UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

A STUDY OF WESTERN YELLOW PINE (PINUS PONDEROSA)
AS THE HOST TREE OF DENDROCTONUS BREVICOMIS

by

N. T. Mirov

N. T. MIROV
Field Assistant

University of California
Berkeley, California
November 22 1928

U. S. GOVERNMENT PRINTING OFFICE: 1928 176133

A STUDY OF WESTERN YELLOW PINE (PINUS PONDEROSA) AS THE HOST TREE OF DENDROCTONUS BREVICOMIS

by

N.T. MIROV
Field Assistant

University of California
Berkeley, California
November 22 1928

A STUDY OF WESTERN YELLOW PINE (PINUS PONDEROSA)

AS THE HOST TREE OF DENDROCTONUS BREVICOMIS

Table of Contents

A STUDY OF WESTERN YELLOW PINE (PINUS PONDEROSA)
AS THE HOST TREE OF DENDROCTONUS BREVICOMIS

This study is an attempt to attack the problem of tree selection by the western pine beetle from a new angle, the purpose being to determine whether or not there are different varieties or forms of western yellow pine which are distinguishable, and if so how the different forms vary in susceptibility to attack by the western pine beetle.

Historical

Very little attention has been paid by botanists to the taxonomic peculiarities of western yellow pine (Pinus ponderosa Laws.) At the present time only two varieties of this species are recognized--typical Pinus ponderosa and P. ponderosa var. scopulorum, the Rocky Mountain form. Some authors consider Pinus jeffreyi a subspecies of P. ponderosa, but as this tree has never been known to be attacked by D. brevicomis it is not included in the present study. Western yellow pine growing on the Pacific Slope, according to botanists, belongs with the typical form of this species; nevertheless this Pacific Slope form varies considerably in morphological characters, as noted by many investigators. Professor J.A. Lemmon (4, 1887-88) distinguished several forms of western yellow pine in California, based upon morphological characters.

Chemical Characteristics of Western Yellow Pine

In the course of time Lemmon's discoveries were forgotten, and it was not until 1912 that the question of possible variations of western yellow pine was again brought up, this time on the basis of chemical characters of Pinus ponderosa. At that time some turpentining experiments were undertaken in California by the U.S. Forest Service, and oleoresin samples were sent to the Forest Products Laboratory at Madison, Wisconsin. The analysis of these samples (by Schorger) showed that the chemical composition of oleoresin from different specimens varied greatly; in fact, the volatile oil of some trees was found to be identical with that of P. ponderosa scopulorum, presumably not found in California. The chemical composition of volatile oil obtained from typical California western yellow pine is as follows:

5% alpha-pinene
65% beta-pinene
20% limonene
10% high-boiling substances of uncertain composition
The oil is levorotatory.

Some of the samples taken in 1912 happened to be dextrorotatory, as if they were of scopulorum form. Oil of one sample, most unexpectedly, was found to be composed almost entirely of limonene. Unfortunately no records were prepared at that time which would show the relation between morphological characters and the chemical composition of oleoresin. Furthermore,

as very few samples were collected, it is impossible to say whether these chemical differences correspond to some well-established forms or varieties or are only differences. Nevertheless, the 1912 experiments are of great value in that they showed that the typical (so-called) form of western yellow pine differs widely in the chemical composition of its oleoresin.

It appears that the validity of chemical characters in taxonomic study is above any doubt. The works of Baker and Smith on Australian Eucalypts (1) and the investigations of Dr. Ting Tames (8) are examples of the value of chemical characters in the solution of difficult taxonomic problems.

PURPOSE OF THE STUDY

From the author's point of view the more extensive study of morphological characters in connection with chemical analysis of oleoresin seemed very desirable. If there are some well-established forms of western yellow pine on the Pacific Coast, we may suppose that some of these forms are less susceptible to Dendroctonus brevicomis attacks than others. In order to obtain more information regarding this question it was proposed to select a number of specimens of western yellow pine which would show the greatest possible variation in morphological characters and to analyze the chemical composition of their oleoresin. It was hoped that this would aid in determining whether the "typical" western yellow pine includes a number of forms or varieties.

It was supposed that some of the trees weakened by the scarification necessary for obtaining oleoresin would be attacked by D. brevicomis in the near future. (It was observed in the case of Jeffrey pine tapping in Harvey Valley, Lassen National Forest, that about four per cent of the tapped trees were killed within one year following tapping by a rather slow-working beetle--Dendroctonus jeffreyi Hopk.) This would give an opportunity to find out the correlation between the chemical composition of oleoresin and D. brevicomis tree selection. Of course it would be much simpler to collect oleoresin samples from trees already attacked; but the difficulty is that as soon as a tree is infested the oleoresin yield is so greatly decreased that it is impossible to obtain an amount sufficient for its analysis. Furthermore, it was hoped that some data might be obtained in regard to the oleoresin production of fast- and slow-growing trees. It has been assumed that slow-growing trees usually yield less oleoresin than fast-growing trees and are therefore more easily overcome by the barkbeetles.

FIELD PRACTICE

In accordance with the ideas outlined briefly above, one hundred specimens of western yellow pine were selected in cooperation with Mr. Person on the Modoc National Forest. These trees were chosen in four different localities for better emphasizing the possible influence of various environmental conditions (Plate I). Attention was also given to the selection of both susceptible and resistant trees, according to Mr. Person's suggestions.

All trees were tagged, numbered and carefully described in regard to morphological and often anatomical characters (number of resin ducts in needles). An increment core was taken from each tree. The oleoresin yield of each tree was recorded for the purpose of determining the possible relation between oleoresin yield and the amount of D. brevicomis infestation. Oleoresin was collected in friction-top cans, which were numbered and stored awaiting laboratory analysis.

DETAILED DESCRIPTION OF EXPERIMENTAL AREAS

Sugar Hill Area

This area is located in the SE¼ of Sec. 10, T 46 N, R 14 E, MDM; elevation 5400 feet. It occupies a very gentle slope of northwest exposure. The soil is of volcanic origin, well decomposed and fine. The stand is pure western yellow pine with just a few young firs and cedars intermixed, especially on the upper part of the area. The stand has a healthy appearance. The site class varies between 2 and 3. Reproduction is not very abundant and is usually found in patches. Underbrush is represented by a few specimens of Lonicera sp. and Purshia tridentata. Herbaceous vegetation is as a rule very scarce, and is composed of Lupinus, Wyethia and some Gramineae. Ceanothus prostratus is also present. The 1927 D. brevicomis infestation in this area was estimated to be about 5 per cent of the stand. The 1928 infestation showed a marked decline to about 1 per cent. Thirty trees were selected in this area, the diameters varying from 24 to 43 inches (average 29.7). The average number of annual rings in the last inch was 48. A few trees were attacked by Dendroctonus valens soon after the first turpentining scar was made. In the case of one tree (#18) the attack of this beetle was rather severe; later this tree was attacked by D. brevicomis and killed before an amount of oleoresin sufficient for analysis was collected.

Buck Creek Area

The Buck Creek Area is located about half a mile east of the ranger station in Sec. 5 (unsurveyed), T 46 N, R 15 E, M.D.M. The elevation is 5500 feet. The area occupies a fairly steep slope of southwestern exposure of Site 3. The stand is almost entirely composed of western yellow pine with intermixtures of old cedars (Libocedrus decurrens). The reproduction is in patches, sometimes very abundant. The presence of Cercocarpus ledifolius is quite characteristic of this area. Herbaceous vegetation is almost identical with that of the Sugar Hill Area. About 3 per cent of the stand was killed by D. brevicomis in 1927 and probably 1 per cent in 1928. Twenty trees were selected on this area for experimental purposes, with an average diameter of 30.9 inches. The average number of rings in the last inch was 37.8.

Jerome Mill Area

This area is located about one mile north of the old Jerome Mill in the NW¼ NW¼ of Sec. 32, T 46 N, R 15 E, M.D.M. The elevation is 5800 feet. It occupies a gentle northerly slope and may be characterised by the admixture of both incense cedar and white fir with the yellow pine, with abundant reproduction of these two species. Western yellow pines are

overmature, though apparently healthy; the site is between 2 and 3. Infestation for 1927 was found to be below one per cent. Herbaceous vegetation is similar to that of the other areas except that Wyethia is absent. Twenty trees were selected in this area with an average diameter of 37.0 inches, the number of rings in the last inch being 52.8.

Brown's Well Area

It may be seen from the attached map that this is at some distance from the other three areas. It is located in the SE¼ of Sec. 31, T 44 N, R 8 E, M.D.M., the elevation being 5000 feet. This area is located within the limits of an entomological permanent plot and occupies a very gentle slope of eastern exposure, flat in places. The stand may be characterized as pure western yellow pine of Site 3 to 4. The general appearance of the forest is not very favorable. Lichenes hang on lower limbs of trees and some specimens are covered by them up to the top of the crown. It is noteworthy that no cones were seen either on the trees or the ground, although this has been characterized as an exceptionally good seed year and cones have been found in abundance in the stands located east and south of Goose Lake. Reproduction is rather scarce and patchy. Underbrush consisted of Arctostaphylos patula, Ceanothus cuneatus and Purshia tridentata. Herbaceous vegetation was represented (in the middle of July) by scattered specimens of Wyethia, Lupinus, Castilleia, Sidalcea; Ceanothus prostratus covers the ground in places. This area has been very heavily infested by D. brevicomis. The 1927 loss totaled over 10 per cent of the total volume of the stand. The 1928 loss shows a marked decline. Thirty mature trees were selected on this area with an average diameter of 33.6 inches, the average number of rings in the last inch being 49.8. Four infested specimens were included in the total number of experimental trees, but were killed before yielding an amount of oleoresin sufficient for analysis.

DISCUSSION

The summarized features of all four areas are represented in the following table:

Area	No. of experimental Trees	Silvical Characteristics	Elev. (Feet)	Aver. Diam.	Aver. No. of annual Rings, last inch	1927 D.B. Infestation (%)	Average oleoresin yield per cup per week (oz.)
Sugar Hill	30	Pure WYP stand	5400	29.7	47.8	5	3.49
Buck Creek	20	Admixture of incense cedar	5500	30.9	37.8	3	3.52
Jerome Hill	20	Admixture of white fir & incense ced.	5800	37.0	52.8	1-	3.67
Brown's Well	30	Pure WYP stand; presence of Lichenes	5000	33.6	49.8	10	Not taken

The Jerome Mill Area has the best rate of growth, the highest yield of oleoresin and the lowest D. brevicomis infestation of any of the areas. The Brown's Well Area, on the contrary, may be characterized by the smallest growth rate, the highest infestation and apparently the lowest oleoresin yield.*

VARIATION IN MORPHOLOGICAL CHARACTERS

A study of tree description forms demonstrates a very extensive variation of morphological characters of western yellow pine in the experimental areas. From the generally accepted botanical description of *Pinus ponderosa* from California it may be concluded that cones with upward prickles of cone scale tips (8) and sulphur yellow-colored bark scales (2)(4) are the persistent characters of this species. In this study it has been found that cone scale prickles vary much in different specimens, in most cases being pointed upward (~~see photo.~~).

The following table shows variations of this character in our experimental trees:

Area	No. of Experimental Trees	Form of Cone Scale Prickle		
		Upward ~~12,13,14~~	Straight ~~9,10,11~~	Recurved ~~15, 16~~
Sugar Hill	30	20	11	0
Buck Creek	20	13	6	1
Jerome Mill	20	11	6	3
Brown's Well	30	20	4	5
Total	100	64	27	9

It is true that the bark scales of western yellow pine in California are usually of a sulphur-yellow color (2), but many of the experimental trees had scales with a grayish or pinkish hue.

This character was represented by experimental areas as follows:

Area	Number of Trees with Non-Typical Bark Scales	
Sugar Hill	14	(47%)
Buck Creek	4	(20%)
Jerome Mill	1	(5%)
Brown's Well	10	(33%)

Bark appearance also varies much. There is a quite general idea (9) that young, fast-growing trees have rough dark bark, while bark of old, slow-growing specimens of western yellow pine is light and smooth. Our observations showed that trees with both rough and smooth bark may be found in either fast- or slow-growing groups. Some slow-growing overmature trees have been found which have dark brown, deeply furrowed bark. The resin ducts of the needles of 56 trees were counted. This analysis showed that the number of resin ducts that had previously been estimated as two (Schorger (8)) varies from 2 to 13.

*No regular oleoresin yield records were taken on Brown's Well Area.

CHEMICAL STUDIES ARE NECESSARY

From the material available it is impossible to tell how constant all these variations in prickles, bark structure and cones are. There seems to be no correlation between different characters. Nevertheless the study of our field records clearly indicates that specimens selected are far from uniform. This appears to be one of those obscure cases where morphological characters are so intermixed that it would be rather difficult to arrive at a definite conclusion without paying attention to chemical peculiarities in the specimens under consideration.

VARIATION IN OLEORESIN COMPOSITION

Owing to the impossibility of obtaining working space in the laboratories of the University of California and to lack of time, only ten samples of oleoresin have been examined, and these only for the determination of their physical constants--index of refraction and optical rotation. The results of this examination are given in the following table; Schorger's (7) data are also given for comparison:

Present Examination				Schorger's Data (7)			
Tree No.	Morphol. Class. of Trees	Refrac. Index 15°C.	Optical Rotation	Description of Samples	Refrac. Index 15°C.	Optical Rotation	Principal Constituent
2	Typical	1.4755	+19.6	"Bastard Pine" from California	1.4724	+30.33	Alpha-pinene
4	Non-Typ.	1.473	-60.5	P. ponderosa v. scopulorum fm. Ariz.	1.4723	+13.05	"
8	Non-Typ.	1.4770	-13.5	same	1.4729	+12.86	"
22	Non.Typ.	1.4760	-13.0	Non- Pinus	1.4755	-67.57	Limonene
29	Typical	1.4775	-59.0	typ- pond.	1.4770	-27.14	Beta-pinene
36	Typical	1.4750	-21.5	ical from	1.4765	-18.44	"
37	Non-Typ.	1.4760	- 4.0	forms Calif.	1.4733	-12.63	"
59	Typical	1.4760	-23.3	Typ- P.pon.	1.4793	-21.23	"
72	Non-Typ.	1.4757	+16.0	ical from	1.4785	-17.12	"
77	Typical	1.4770	-38.5	forms Calif.	1.4780	-15.73	"

Data obtained this year are in accordance with Schorger's findings in regard to very extensive variations of western yellow pine oleoresin composition. The presence of two trees out of ten having dextrorotatory turpentine is very interesting. It supports Schorger's suppositions that the dextrorotatory Rocky Mountain form might occasionally be found in typical levorotatory stands of the Pacific Coast. The wide range in optical rotation (from +19.6 to -60.5) is another interesting feature of the table. It might be expected that the chemical composition of turpentine from different trees would also vary accordingly. Sample #4 very closely resembles Schorger's sample taken from the "~~Bastard~~ LIMONENE pine" from California. Tree #4 is by no means typical in appearance. Its bark is very smooth, purplish-brown in color, and resembles in texture the bark of sugar pine. Several similar specimens have been found among the experimental trees.

It would be highly desirable to make arrangements with the Forest Products Laboratory at Madison, Wis., for analysis of all the samples, so that the data obtained would be available for the study of the relation, if any, between western pine beetle attacks and the chemical varieties of western yellow pine.

RELATION BETWEEN GROWTH AND PITCH PRODUCTION

The field experiments on western yellow pine have enabled us to obtain some material on the relation between tree growth and pitch production. This may be of interest from the entomological point of view. Usually considerable stress is laid upon the pitch yield of trees, on the supposition that slow-growing trees, if attacked by bark-beetles, produce a smaller amount of oleoresin than fast-growing trees, and are thus less resistant to attack. Plate II shows 70 experimental trees plotted according to weekly yield of oleoresin and rate of growth. It is seen that the good yielding trees may be found among both fast- and slow-growing trees (cf. Nos. 26, 4 and 28), and that trees of the same rate of growth do not always yield the same amount of oleoresin (cf. Nos. 3 and 64); on the contrary, there is a considerable individual variation. It seems, therefore, that the western pine barkbeetle in its preference for slow-growing trees is not concerned with the amount of oleoresin which it would find in such trees.

In the author's recent report on attraction studies with the western pine beetle it was brought out that beetles are more concerned with the nutritive substances of the phloem than with the volatile oils of the bark and wood. The present experimental data agree as evidence that in the question of tree selection by D.b. the role of oleoresin is of secondary importance.

SUMMARY

This study was undertaken in the hope of finding different forms of Pinus ponderosa and checking out the possible correlation between D. brevicomis attacks and morphological as well as chemical variations of its host species. Previous investigations have thrown some light on the great variations of Ponderosa species. Present investigations fully support this point of view. Examination of several samples of volatile oils obtained from the oleoresin of different trees showed that their physical characters (index of refraction and rotation power) vary to a great extent; and it was therefore supposed that the chemical composition varied accordingly.

A more complete examination of oleoresin collected during the field season is urgent. It is felt that the study of the above-mentioned correlation may be completed after several years of field checking of experimental trees.

During the turpentining experiments it was found that there is very slight if any correlation between growth rate and oleoresin exudation. It was therefore concluded that D. brevicomis in its preference for slow-growing trees does not depend entirely on the smaller oleoresin exudation in these trees. Probably other factors, such as the products

of the phloem, are more important. This question is discussed more fully in the author's recent report on D. brevicomis attraction studies.

LITERATURE CITED

1 BAKER, R.T. and SMITH, H.G.
A Research on the Eucalypts, especially in regard to their essential oils. Technological Museum, New South Wales; Sydney, 1920.

2 JEPSON, W.L.
The Trees of California; 1923; p. 40.

3 LAMB, W.H.
Turpentine Possibilities on the Pacific Coast; Discussion. Proc. Soc.Amer.For.,Vol.9,No.3,pp.327-341.

4 LEMMON, J.G.
Report of the Botanist; 2nd Bien.Rep.Calif.State Board of For., 1887-88; and 3rd Bien.Rep., 1889-90 (Revision of Broken Cone Pines.

5 SCHORGER, A.W.
Contribution to the Chemistry of American Conifers; Trans.Wis. Acad.Sci.Arts & Let.,Vol.1,19,Part 2; 1919.

6 ----
Oils of Coniferae; Jour.Ind.and Eng.Chem.,V.6,No.11,1914.

7 ----
Chemistry as an Aid in the Identification of Species; Proc.Soc.Am. For. 11, V.11, No.6;1916.

8 TINE, TAMES
Dipsacan und Dipsacotin; ein neues Chromogen und ein neuer Farbstoff der Dipsacaceae. Recueil des Traveaux Botaniques Neerlandais, 1908; Notiz v.d. Vorkommen von Dipsacan bei den Dipsacaceae; ibid, 1911.

9 SUDWORTH, G.B.
Forest Trees of the Pacific Slope; 1908; p. 42.

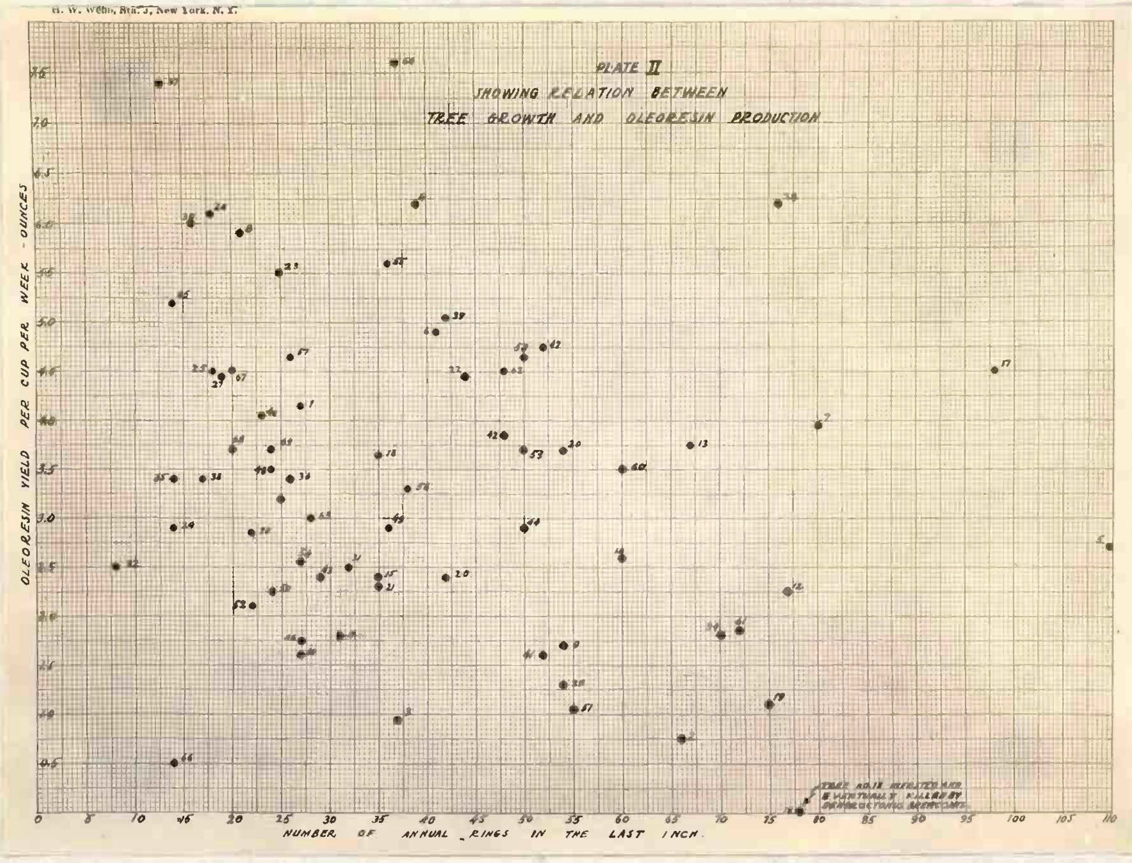


Photo 1

Jerome Mill
Experimental Area

Photo 2

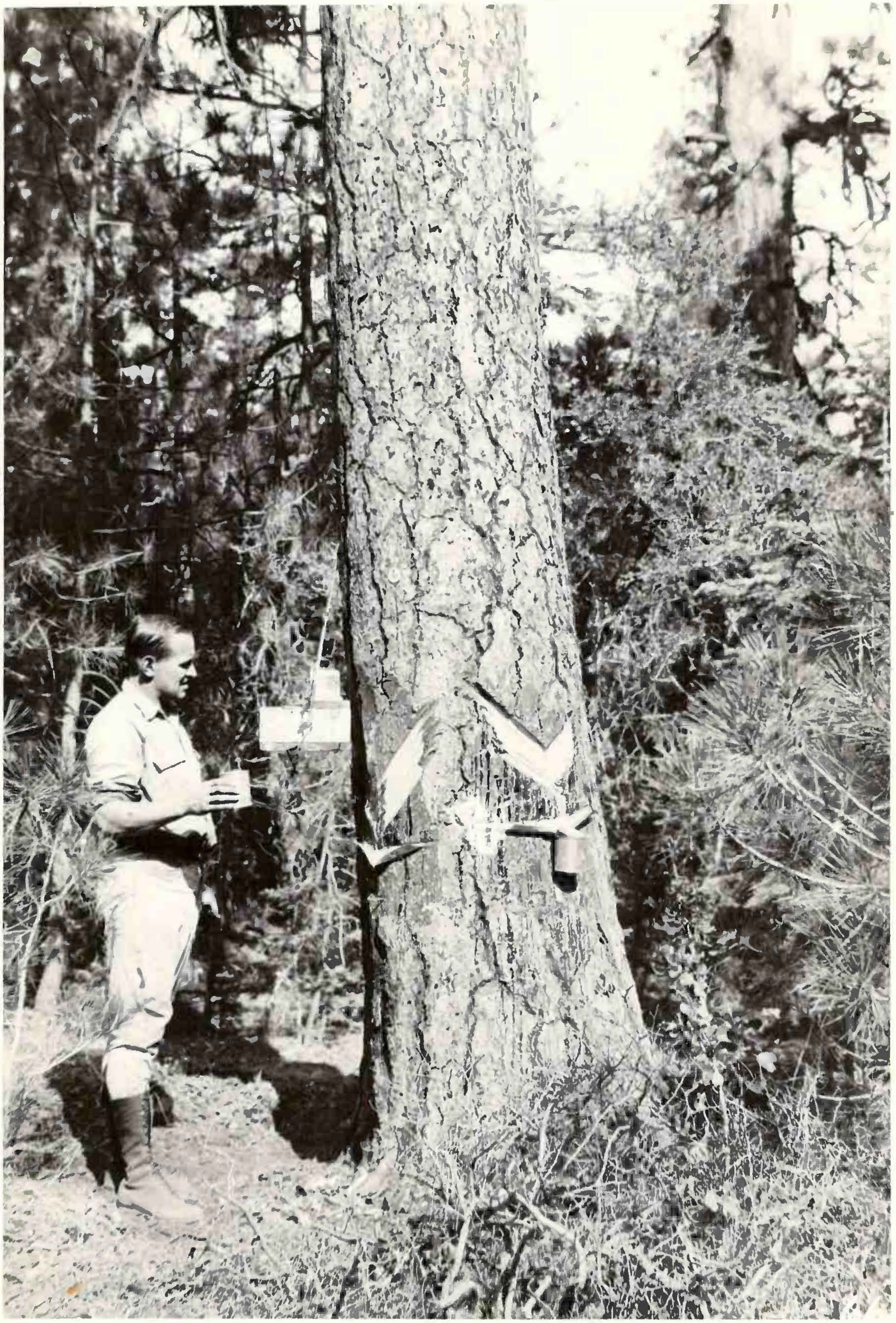
Buck Creek
Experimental Area

Photo 3   Part of Sugar Hill Experimental Area
showing types of trees studied

Photo by Person

Photo 4 Illustrating method of collecting and weighing oleoresin samples

Photo by Person



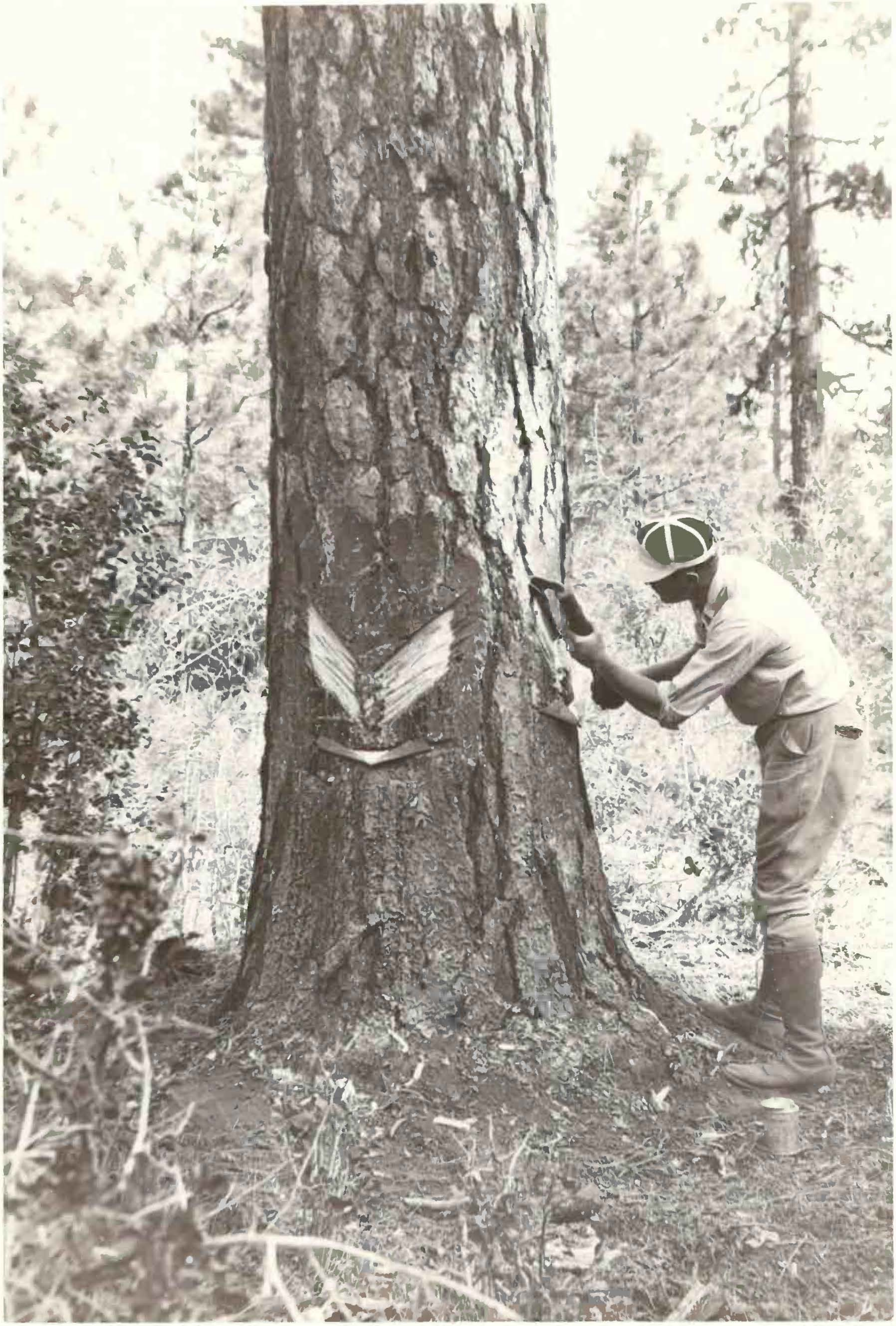
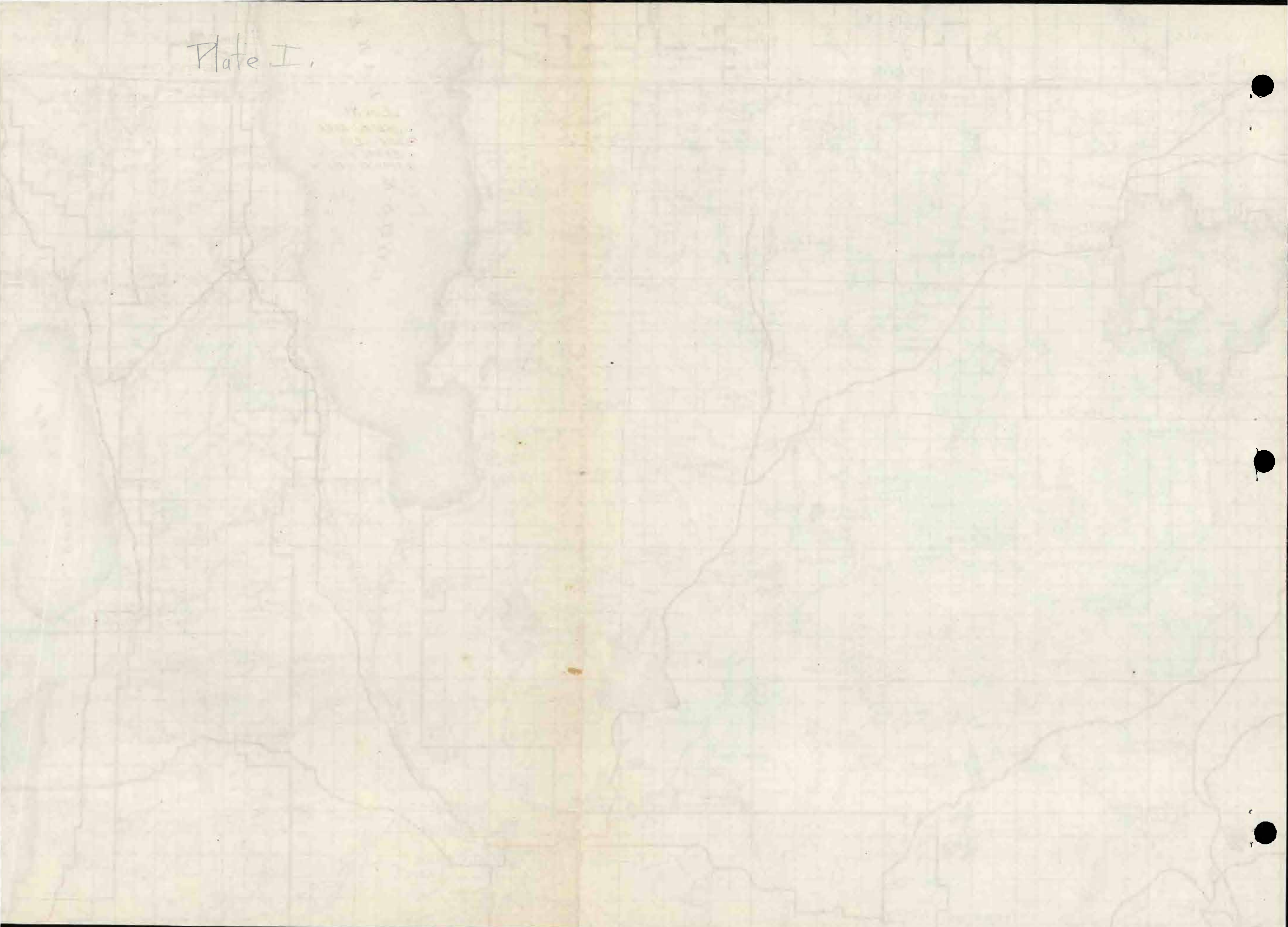
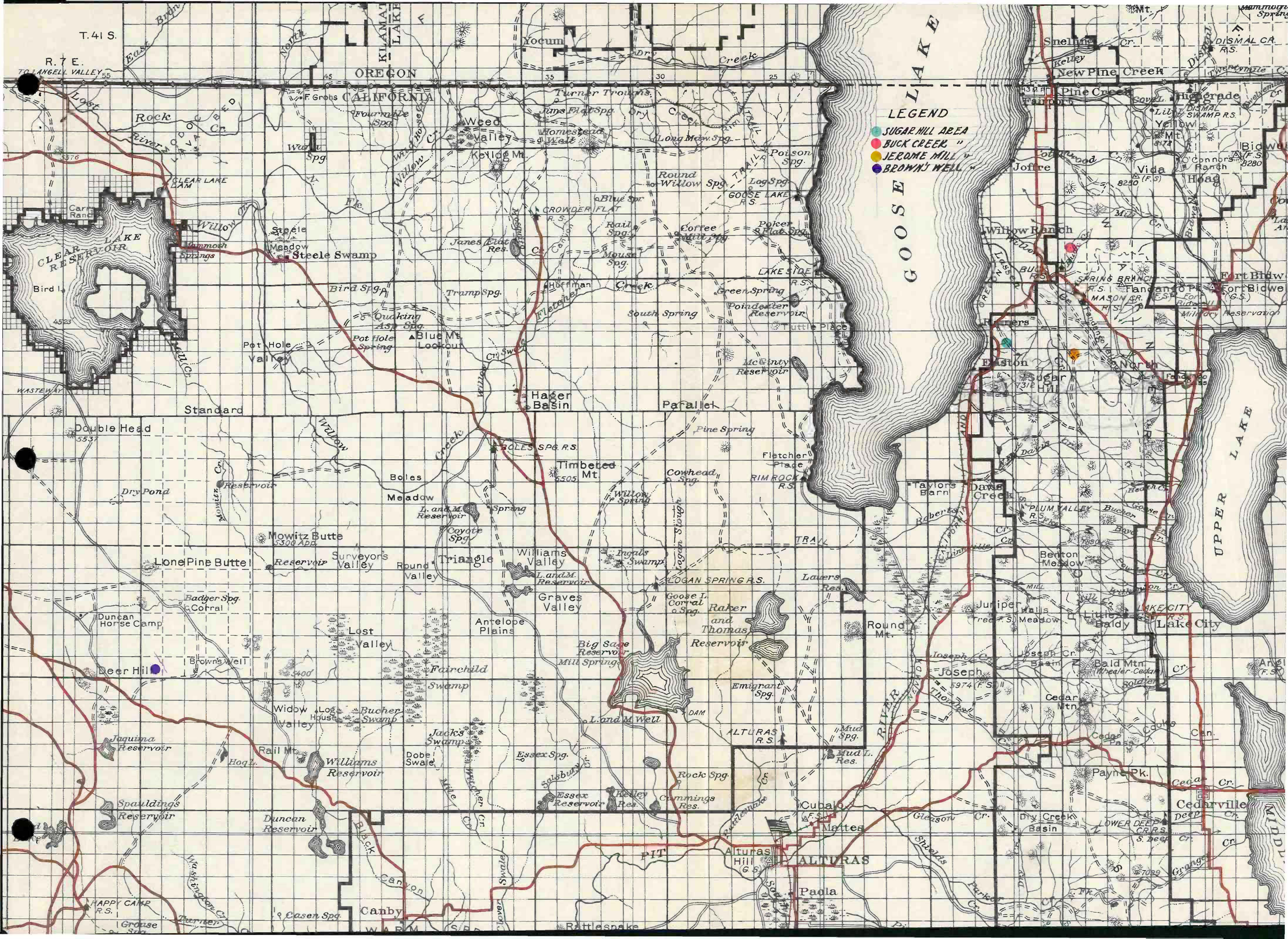


Photo 5 Method of scarification used in collection of oleoresin from experimental trees

Photo by Person

Plate I.





LEGEND
SUGAR HILL AREA
BUCK CREEK "
JEROME MILL "
BROWN'S WELL "
T. 41 S.
R. 7 E.
TO LANGELL VALLEY
OREGON
CALIFORNIA
KLAMATH LAKE
GOOSE LAKE
UPPER LAKE
CLEAR LAKE RESERVOIR
CLEAR LAKE DAM
Lost River
Rock Cr.
MODOC LAVA BED
Bird I.
Carr Ranch
Willow Cr.
Mammoth Springs
Steele Meadow
Steele Swamp
Yocum
Dry Creek
Turner Troughs
F. Grohs
Fourmile Spg.
Weed Valley
Kellog Mt.
Homestead Well
Jims Flat Spg.
Long Mdw. Spg.
Poison Spg.
Round Willow Spg.
Log Spg.
GOOSE LAKE R.S.
CROWDER FLAT R.S.
Blue Spr.
Rail Spg.
Coffee Mill Spg.
Poker Flat Spg.
Janes Flat Res.
Mouse Spg.
LAKE SIDE R.S.
Bird Spg.
Tramp Spg.
Huffman
Fletcher Creek
Green Spring
Poindexter Reservoir
South Spring
Tuttle Place
Quaking Asp Spg.
Blue Mt. Lookout
Pot Hole Spring
Pot Hole Valley
McGinty Reservoir
Hager Basin
Parallel
Standard
WASTEWAY
Double Head 5537
Pine Spring
BOLES SPG. R.S.
Timbered Mt 5505
Fletcher Place
RIM ROCK R.S.
Cowhead Spg.
Willow Spring
Dry Pond
Reservoir
Boles Meadow
L. and M. Reservoir
Spring
Coyote Spg.
Mowitz Butte 5300 App.
Surveyors Valley
Round Valley
Triangle
Williams Valley
Ingalls Swamp
Logan Slough
Lone Pine Butte
L. and M. Reservoir
LOGAN SPRING R.S.
Lauers Res.
Badger Spg. Corral
Graves Valley
Goose L. Corral Spg.
Raker and Thomas Reservoir
Round Mt.
Duncan Horse Camp
Lost Valley
Antelope Plains
Big Sage Reservoir
Mill Spring
Deer Hill
Brown's Well
Fairchild Swamp
Emigrant Spg.
Widow Valley
Log House
Bucher Swamp
L. and M. Well
DAM
ALTURAS R.S.
Mud Spg.
Jaquima Reservoir
Jacks Swamp
Rail Mt.
Hog L.
Williams Reservoir
Dobe Swale
Essex Spg.
Salsbury Cr.
Mud L. Res.
Rock Spg.
Spauldings Reservoir
Essex Reservoir
Kelley Res.
Cummings Res.
Duncan Reservoir
Black Canyon
Cubalo
Mettes
Alturas
ALTURAS
Hill G.S.
PIT RIVER
Gleason Cr.
Shields Cr.
Paola
Canby
HAPPY CAMP R.S.
Grouse Spg.
Casen Spg.
Rattlesnake
Snelling
New Pine Creek
Pine Creek
Fairport
Highgrade
DISMAL SWAMP R.S.
DISMAL CR. R.S.
Lily Yellow Mt.
Joffre
Cottonwood Cr.
Vida
O'Connors Ranch
Hoag
Bidwell
Willow Ranch
Buck
SPRING BRANCH R.S.
MASON CR. R.S.
Fandango P.
Fort Bidwell
Military Reservation
Fanners
Easton
Sugar Hill
North
Davis Creek
Taylors Barn
PLUM VALLEY R.S.
Benton Meadow
Juniper
Halls Meadow
Little Baldy
LAKE CITY R.S.
Lake City
Joseph Cr.
Joseph
Bald Mtn.
Cedar Mtn.
Cedar Pass
Payne Pk.
Cedarville
Dry Creek Basin
LOWER DEEP CR. R.S.